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# METHODS FOR THE DETERMINATION OF ORGANIC MATTER IN AIR.

BY

DAVID HENDRICKS BERGEY, B.S., M.D.,

Holder of the Thomas A. Scott Fellowship in Hygiene, 1894–'95, Laboratory of Hygiene, University of Pennsylvania, Philadelphia, Pa.

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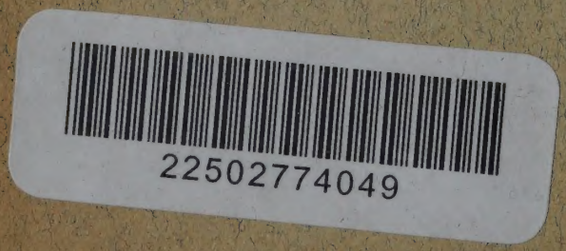

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# METHODS FOR THE DETERMINATION OF ORGANIC MATTER IN AIR.

By David Hendricks Bergey, B.S., M.D.

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A number of methods have been devised for the estimation of organic matter in air. The results that have been obtained by these different methods are, however, quite variable even under the same atmospheric conditions. The difficulties that were encountered in estimating the quantity of organic matter in expired air, while conducting the research on The Composition of Expired Air and its effects upon Animal Life,[1] demonstrated the fact that some of the methods in use were unsatisfactory. At the suggestion of Dr. Billings some of these methods have been tested and compared as to their reliability and adaptability for hygienic investigations.

The methods that are now in use fall into two groups. In the first group of methods the organic matter is converted into ammonia either by the Wanklyn, Chapman, and Smith[2] process and estimated with Nessler's reagent; or by direct nesslerization of the absorbent used to abstract the organic matter from the air; or, as in one of the methods, the distillate is carried into dilute sulphuric acid and the amount of free acid estimated by titration with deci-normal ammonia.

In the second group of methods the organic matter is oxidized by boiling with a dilute solution of permanganate of potash, and titrating with oxalic acid solution, as in the estimation of organic matter in water.

All these different methods are colorimetric in their nature. They are also only indirect methods inasmuch as they afford no clue as to the nature or quantity of organic matter—as such—that is present in the air; the end-products in all of the methods being of an entirely different nature from the organic matter itself.

The modifications of the methods of both groups by different experimenters consist principally in variations as to the form of absorbent used and the modes of absorption, or in the manner of applying the reducing agents. In most instances the modifications of the apparatus employed are of minor importance.

The methods of the first group have much in common. Chapman[3]

took advantage of the process devised by Wanklyn, Chapman, and Smith [2] for the estimation of organic matter in water by its conversion into free and albuminoid ammonia, and adapted it to the estimation of organic matter in air. He aspirated the air through cotton-wool, or through gun-cotton, asbestos, or pumice-stone, and then subjected the absorbent to distillation, thereby converting the organic matter derived from the air into ammonia. He found that aspiration through asbestos gave the most reliable results.

Moss [4] passed a measured quantity of air through four wash bottles of 100 c.c. capacity, each containing 50 c.c. of pure distilled water, except the first, which contained also 50 c.c. of pure hydrochloric acid. The absorbent solutions are then subjected to distillation and the ammonia evolved from the organic matter estimated with Nessler's reagent.

R. Angus Smith [5] aspirated measured volumes of air through pure distilled water contained in an absorption tube. The water is then subjected to distillation and the ammonia estimated by means of Nessler's reagent.

The method employed at the Montsouris [6] Observatory, near Paris, consists in drawing a known volume of air through bent tubes or through a "rose," laid in a cooling mixture. The suspended particles in the air are condensed and retained, and are then taken up with pure distilled water; or in addition to the cooling mixture the air is conducted through pure distilled water. The distilled water containing the suspended matter from the air is then subjected to distillation and the ammonia estimated by means of Nessler's reagent.

In the laboratory of the Medical Officer of Health,[7] in Glasgow, the apparatus employed at the Montsouris Observatory is slightly modified. The air is drawn through a "rose" which is placed in a small vessel containing a quantity of small glass beads lying in dilute sulphuric acid. The sulphuric acid and beads are then transferred to a clean retort, the acid is neutralized with solution of sodium carbonate, when the estimation of ammonia is conducted in the usual manner.

Fodor [8] uses two U-shaped tubes containing pure distilled water acidulated with sulphuric acid. The air is filtered through glass-wool and the amount of organic matter in the dust is determined by distillation, as well as the amount contained in the acidulated water. The two absorbents are subjected to distillation separately, thus showing the amount of organic matter in each of them.

Lehmann [9] recommends Uffelmann's method in which the air is aspirated through two small flasks, the one containing a dilute solution of sulphuric acid and the other a dilute solution of caustic potash, each of about one per cent. strength. These solutions are then mixed and

the oxidizable matter determined by distillation and testing with Nessler's reagent.

A modification of Chapman's method which has met with considerable favor consists in the aspiration of a known volume of air through freshly ignited finely granular pumice-stone contained in a narrow absorption tube. The subsequent treatment of the pumice-stone is similar to that first employed by Chapman. This method was devised by Professor Remsen [10] and has since been used by Miss Talbot [11] and by Dr. Abbott.[12]

Smee [13] employs a large glass funnel, sealed at the neck, and filled with cracked ice. The moisture and suspended particles in the air are condensed on the exterior surface of the funnel and are collected in a small beaker placed underneath the funnel. The condensations are then subjected to distillation and the ammonia estimated by means of Nessler's reagent.

Fox [14] prefers what he calls the "pulverization of water method." It consists in bringing consecutive portions of fresh air into intimate contact with a small quantity of very pure water which is being reduced to a minute state of subdivision by pulverization in a glass cylinder about eight inches in length and two inches in diameter, and which is furnished with a large india-rubber stopper. This stopper has two perforations, into one of which the air pipe of a Bergson's spray producer is fitted; the other is intended for the passage of a straight glass tube about twelve inches long and one-fourth inch in diameter. Thirty cubic centimetres of pure distilled water are placed in the cylinder, and this serves to wash the air of all its impurities as it passes through the fine spray formed in the cylinder by the spray-producer. The thirty cubic centimetres of water used are then diluted to 100 c. c. with distilled water, and the whole subjected to distillation in a small retort, the distillates being tested for ammonia with Nessler's reagent.

Miss Talbot [11] concluded, as the result of some determinations made with Remsen's method, that all of the organic matter fails to be converted into ammonia during the first distillation. She found that the second and third re-distillation of the distillates uniformly give higher results. She sought to overcome this difficulty by aspirating the air directly through the boiling permanganate in the retort.

Dr. Abbott [12] found, as the result of his investigations, that in "31 estimates made upon the outside air, the air of the laboratory, air from over decomposing meat infusions, and the air from over sewage, we have failed to obtain evidence of the existence of more than a trace of gaseous, nitrogenous, organic matters, other than ammonia; the amounts being constantly so small as to fall far below the permissible limits of experimental error."

For the direct estimation of ammonia in air Uffelmann [15] employs the following method: Twenty to thirty litres of air are aspirated through 10 c. c. of dilute sulphuric acid; this is then tested with Nessler's reagent and the color produced compared with that of a solution of ammonium chloride of known strength. He uses 0.3147 g. $NH_4Cl$ in 1 litre of water, which is equal to 0.100 g. $NH_3$ to the litre. This solution is diluted with water (for the comparison) until its color is similar to that produced by the sample of air. A yellow color indicates 0.005 mg. $NH_3$ in 100 c. c. of water.

A method which I employed in an earlier series of experiments [1] consists in conducting measured volumes of air through a coil of glass tubing laid in ice so as to condense the atmospheric moisture and dust. The fluid collected in this manner is then subjected to distillation. The chief difficulty in this method is the slowness with which the condensation of moisture takes place. It is only on days when the atmosphere is nearly or completely saturated with moisture that an appreciable amount of fluid is collected. On clear days the evaporation of the moisture often exceeds the condensation, and in consequence the fluid already collected may be lost through evaporation.

A method employed by Gray,[16] of New Zealand, consists in collecting the rain water as it falls and subjecting it to distillation.

The methods of the second group also have a common object, the determination of the amount of oxygen required to oxidize the organic matter in a known volume of air. These methods differ, however, very greatly as to the forms of apparatus employed by the different experimenters.

R. Angus Smith [5] used a flask of about 100 cu. in. (1175 c. c.) capacity. The air is pumped out of the flask by means of a hand bellows, so that the air of the place may pass in to take its place. The flask is then closed with a rubber stopper perforated by two holes, the one containing a glass tube through which a weak solution of permanganate of potash is introduced from a small burette; the other opening allows the air that is displaced by the permanganate solution to escape. A small quantity of the permanganate solution is used at first and agitated with the sample of air. More of the permanganate solution is added as fast as it is being decolorized, a permanent color indicating that the "air contained no more material capable of decomposing permanganate." The solution of permanganate which Smith used was of such strength that 1 c. c. tested with proto salt of iron equalled 0.00225 g. of metallic iron, or, 0.00032 g. of oxygen. Alkaline salts seemed to him to be more sensitive than pure permanganate.

A second method devised by Smith is as follows: Thirty cubic centimetres of water containing a small amount of a weak solution of

permanganate of potash of known strength, are shaken with the air in a flask of known capacity. The flask is refilled with air and again shaken—"air washing,"—and this process is continued until all the permanganate is decolorized. The volume of air required to decolorize the permanganate will indicate the quantity of organic matter contained in it.

Uffelmann[15] determines the quantity of organic matter in air by means of a solution of permanganate of potash, of which 1 c. c. equals 0.395 mg. of $KMnO_4$, or 0.1 mg. of oxygen, and requires 0.7875 mg. of oxalic acid to neutralize it. The permanganate solution is placed in a small flask, the stopper of which carries two glass tubes. One of these tubes is of sufficient size to serve as a dust-filter and contains freshly ignited asbestos or glass-wool; the other tube serves to connect the apparatus with a small aspirator, about one litre in capacity. The apparatus is cleansed with hot permanganate solution. One cubic centimetre of the permanganate solution is then placed in the flask with 9 c. c. of pure distilled water, and acidulated with several drops of dilute hydrochloric acid. Ten to twenty litres of air are aspirated through the apparatus. The asbestos or glass-wool absorbent is transferred to a clean casserole with 60 c. c. of distilled water; 2 c. c. of $KMnO_4$ solution and 1 c. c. of dilute sulphuric acid are added and boiled for five minutes. The unreduced permanganate remaining in solution is then titrated with oxalic acid solution. The permanganate solution in the flask is treated in the same manner. The two results will show the quantity of gaseous and of dust-form of organic matter in the air aspirated through the apparatus.

A second method devised by Uffelmann is as follows: Two flat-bottomed test-tubes, each closed with a double-bored rubber stopper, are attached to each other. A dust-filter of asbestos or of glass-wool is attached to the entrance-tube of the first test-tube. The first of these test-tubes contains a dilute solution of caustic potash and the second a dilute solution of sulphuric acid; each solution being of about 1 per cent. strength. By means of a rubber syringe of 50 c. c. capacity, 10 to 20 litres of air are pumped through the apparatus. The two solutions are then mixed and the amount of organic oxidizable matter determined in the usual manner.

Carnelley and Mackie[17] employ a solution of permanganate of potash of $\frac{n}{1000}$ strength, 1 c. c. of which equals 0.008 mg. of oxygen, or 0.0000056 litres of oxygen at 0° C. and 760 mm. The solution is usually kept of $\frac{n}{10}$ strength and diluted as required; about 50 c. c. of dilute sulphuric acid (1 : 6) being added to each litre of the weak solution. For the collection of samples of air large, well-stoppered jars, of about 3.5 litres capacity, are used. The jars are first rinsed with a

little of the standard permanganate, and when not in use some of the solution is always kept in them so as to assure complete cleanliness from any reducing substance. Before using the jars are drained. The sample of air is collected by pumping out the air contained in the jars with a small hand bellows and allowing the air to be examined to flow in. Fifty cubic centimetres of the standard solution of permanganate are run into each jar, when it is tightly stopped and well shaken for at least five minutes. Twenty-five cubic centimetres of the permanganate solution are then withdrawn by means of a pipette and placed in a glass cylinder holding about 200 c. c. Twenty-five cubic centimetres of the fresh standard solution are placed into a similar glass cylinder for comparison. Both of these solutions are then diluted up to 150 c. c. with distilled water and allowed to stand for ten minutes, after which the tints of the two solutions are compared. Standard solution of permanganate is now run into the first cylinder from a burette, until the tints of both solutions are of the same intensity; usually from $\frac{1}{2}$ to 6 c. c. of the standard solution are required. The amount of standard solution added to the solution in the first cylinder is a measure of the bleaching effected by the organic matter in the known volume of air on one-half of the permanganate employed. The results may be expressed either in terms of the number of cubic centimetres of the $\frac{n}{1000}$ solution bleached by 1 litre of air, or, as they prefer, by the number of volumes of oxygen required to oxidize the organic matter in, say, 1,000,000 volumes of air, *i. e.*, the 25 c. c. of solution from a 3.5 litres flask, in which 50 c. c. of standard solution had been used, required 3 c. c. to bring its tint up to that of the cylinder containing the fresh standard, or the entire 50 c. c. would have required 6 c. c. This represents the number of cubic centimetres of standard permanganate bleached by $3{,}500 - 50 = 3{,}450$ c. c. of air; consequently $\frac{6}{3 \cdot 45} = 1.74$ c. c. is the bleaching effected by 1 litre of air, or 0.0000097 litre of oxygen, or 9.7 volumes of oxygen are required to oxidize the organic matter in 1,000,000 volumes of air. Correction for temperature is considered unnecessary, as its effect falls within the limits of experimental error.

Nékám [18] repeated Uffelmann's experiments, giving particular attention to the question whether all of the organic matter is absorbed by the permanganate; and also whether the permanganate suffers reduction from other reducing agents in the air. He found the permanganate to undergo spontaneous reduction while it oxidizes the organic matter very slowly.

Archarow [19] also employed Uffelmann's method, but so modified the apparatus as to conduct the air through the permanganate in a fine stream. The permanganate was also kept at a somewhat higher tem-

perature than the surrounding air, about 43° C., as this was found to facilitate the oxidation of the organic matter. The best results were obtained with acid permanganate solution. The accuracy of the method diminishes with the concentration of the permanganate solutions—a solution containing 0.026 mg. $KMnO_4$ to the litre being most satisfactory.

Some of the methods which have been here reviewed have been tested in this laboratory a number of times in order to determine their reliability. In most instances the same method of absorption was resorted to for the estimation of either the ammonia or the reducing power of the organic matter in the air. It was possible therefore to estimate the quantity of organic matter in the air in terms of both the end-products which have served thus far for the estimation of organic matter by the various experimenters.

In those methods in which the organic matter is converted into free and albuminoid ammonia the retort and condenser used for the distillation process are previously rendered free from ammonia by the prolonged distillation of distilled water that contains but very small proportions of ammonia. The absorbent material, whatever the form that has been used, is transferred to the clean retort and diluted with a sufficient quantity of twice distilled water to bring the whole amount up to 500 c. c. The preparation of sufficient quantities of twice distilled water having a low ammonia-content is not always an easy matter. This is especially the case with the laboratory water-supply. The sewage contamination of the water supply is so marked as to make it impossible to remove all the ammonia in the second distillation, owing to the presence of considerable quantities of urea in it. By using spring water this difficulty was largely obviated. In each determination it is necessary to deduct the ammonia-content of the distilled water that was used to dilute the absorbent material from the results obtained for the determination.

In those methods in which the reducing power of the organic matter upon permanganate was determined the process was carried out in a porcelain casserole which had previously been cleansed by boiling with some of the permanganate solution. The strength of the solution of permanganate of potash employed was 0.4 g. to the litre of water, and was titrated before each experiment against a solution of oxalic acid containing 0.7875 g. to the litre of water, and 10 c. c. of which equalled 1 mg. of oxygen. In these methods it is also necessary to make deductions from the results obtained for each determination for the amount of oxygen consumed by the organic matter in the twice distilled water that had been used to dilute the absorbent material to 100 c. c. In each determination 6 to 8 c. c. of permanganate solu-

tion are added to the diluted absorbent material, and also 5 c. c. of 25 per cent sulphuric acid, and the boiling continued for five minutes.

## Method I.

*A.* Total oxidizable matter. In this method the total oxidizable matter in air is determined by aspirating a known volume of air through 100 c. c. of twice distilled water, contained in a Pettenkofer absorption tube, and then determining the amount of oxygen consumed by this absorbent as compared with the same amount of the water before the experiment, the difference between the two results representing the amount of reduction produced by the organic matter in the volume of air aspirated. The results obtained by this method are given in Table II; the form of apparatus employed is shown in Fig. 1.

*B.* Free and albuminoid ammonia. The free and albuminoid ammonia is determined in the 100 c. c. of twice distilled water, used as the absorbent material in this method, and through which a known volume of air has been aspirated, and the amount of ammonia found in the same quantity of the water before using is deducted from the results of each of the determinations. The results obtained by this method are shown in Table I; the form of the apparatus is the same as that shown in Fig. 1.

## Method II.

*A.* Determination of the gaseous and dust-form of organic matter in air, according to the method of Uffelmann. A small Erlenmeyer flask, of 100 c. c. capacity, and closed with a rubber stopper having two openings, contained the absorbent material which in this method is 25 c. c. of $\frac{n}{2000}$ solution of permanganate of potash acidulated with sulphuric acid. The openings in the rubber stopper of the flask carry two short pieces of glass tubing; the one is connected at its upper extremity with a small globe-shaped glass tube containing freshly ignited asbestos or glass-wool, and the lower extremity of the tube extends nearly to the bottom of the flask. The other glass tube is bent at right angles just above the stopper, and terminates just below the inner edge of the stopper. The other end of this tube is connected with the aspirator.

The gaseous form of organic matter is retained in 25 c. c. of permanganate solution in the flask. Its amount is determined by diluting the permanganate solution with 75 c. c. of twice distilled water and boiling in the ordinary manner, deducting the amount of oxygen consumed by the 75 c. c. of water from the end-result.

The dust-form of organic matter is determined by transferring the asbestos or glass-wool absorbent to a clean casserole, adding 100 c. c. of twice distilled water, 6 to 8 c. c. of permanganate solution, and 5 c. c. of 25 per cent. sulphuric acid, and then boiling for five minutes and titrating with oxalic acid solution in the usual manner. In each determination it is necessary to deduct the amount of oxygen consumed by the 100 c. c. of water from the end-result. The results obtained for the gaseous and dust-form of organic matter in air by this method are given in Table III; the form of apparatus employed is shown in Fig. 2.

## Method III.

*A.* Total oxidizable matter. This method is a modification of that employed by Remsen. The air is aspirated through freshly ignited and finely granular pumice-stone contained in a glass absorption tube, 18 c. m. in length and 1 c. m. in diameter. The pumice-stone is then washed into a clean casserole with 100 c. c. of twice distilled water, and the oxidizable matter determined in the usual manner. From the results so obtained it is necessary to deduct the amount of oxygen consumed by the 100 c. c. of water, and by a similar amount of the pumice-stone before it is exposed to the air. In some of the experiments a dust-filter of freshly ignited asbestos was prefixed to the absorption apparatus to exclude all dust. The results obtained by this method are given in Table VI; the apparatus employed in this method is shown in Fig. 3.

*B.* Free and albuminoid ammonia. Remsen's method. By this method the free and albuminoid ammonia are determined by transferring the finely granular pumice-stone, through which a known volume of air has been aspirated, to a clean retort with 500 c. c. of twice distilled water. Before beginning the aspiration of air the pumice-stone is moistened with some twice distilled water. From the results obtained in each determination it is necessary to deduct the amount of ammonia given off by the same amount of water, as well as by the same amount of the pumice-stone. The results obtained by this method are shown in Tables IV and V; the apparatus employed is shown in Fig. 3.

## Method IV.

*A.* Carnelley and Mackie's method. In this method the air contained in a four- to six-litre flask is agitated with 50 c. c. of $\frac{n}{1000}$ solution of permanganate of potash for about five minutes. Then 25 c. c. of the permanganate solution are placed into a flat-bottomed glass cylinder of such size that it is filled to within about 5 c. m. of the top

when the permanganate solution is diluted with 125 c. c. of twice distilled water. Another glass cylinder of similar size contains 25 c. c. of fresh permanganate solution diluted with 125 c. c. of water. The tints of the solutions in these cylinders are compared after about ten minutes, and the tint of the solution in the first cylinder is deepened so as to compare with that in the second cylinder by the addition of a few drops of the $\frac{n}{1000}$ solution of permanganate from a burette. The amount of permanganate solution required for this purpose indicates the bleaching effected on one-half of the permanganate solution in the flask by the organic matter in the air which it contained. Since 1 c. c. of the $\frac{n}{1000}$ permanganate solution is equal to 0.008 mg. of oxygen, it is easy to calculate the number of milligrammes of oxygen required for the entire sample of air used. The results obtained in this method are given in Table VII.

*B.* Carnelley and Mackie's method modified. This method differs from the foregoing in that the permanganate solution is run into the flask from a burette until no further bleaching effect is noted. The flask contains 50 c. c. of pure distilled water, and the bleaching effected is shown by the tint of the water after it has been agitated with the sample of air for several minutes. The permanganate solution is added until a very faint rose tint is perceptible in the water and remains permanent for five minutes. The permanganate solution used in this method is $\frac{n}{2000}$ strength; 1 c. c. equals 0.004 mg. of oxygen. The number of cubic centimetres of the permanganate solution required to produce the faint rose tint in the 50 c. c. of water will indicate the amount of organic matter in the sample of air used. The results obtained by this method are given in Table VIII.

## Method V.

*A.* In this method the ammonia in the air is estimated directly, by aspirating the air through a $\frac{n}{10}$ solution of sulphuric acid (100 c. c.) which is contained in a Pettenkofer absorption tube and afterward titrating the acid with a $\frac{n}{10}$ solution of ammonium hydroxid, 1 c. c. of the ammonium hydroxid solution being equal to 1.7 mg. of $NH_3$. The results obtained with this method are given in Table IX; the apparatus employed is shown in Fig. 1.

*B.* By aspirating the air through 100 c. c. of pure distilled water contained in a Pettenkofer absorption tube and nesslerizing; the depth of the color produced being compared with standard ammonium chloride solution. The results obtained with this method are given in Table X.

*C.* Uffelmann's method, by aspirating the air through 10 c. c. of diluted sulphuric acid and titrating with Nessler's reagent.

### Method VI.

By this method the sulphuretted hydrogen and the sulphurous acid gas in the air are determined directly by aspirating air through a Pettenkofer absorption tube containing 100 c. c. of a $\frac{n}{10}$ solution of iodine. The quantity of iodine remaining unchanged in the solution is determined by titrating with a $\frac{n}{10}$ solution of sodium hyposulphite, using starch paste as an indicator. One c. c. of the sodium hyposulphite solution is equal to 1.7 mgs. of $H_2S$, or 3.2 mgs. of $SO_2$. The results obtained by this method are given in Table XI.

The results obtained by these methods show quite variable amounts of organic matter in the air. This is what one would expect to find, but the great difficulty in such an investigation is that it is not possible to make satisfactory control experiments. There is no possibility of establishing a standard for comparison, yet by making simultaneous determinations with the different methods on the same air some idea as to their reliability may be obtained. The experimental error in each of the methods is necessarily very large, and in some of the methods is so great as to render them almost entirely useless. The more cumbersome the apparatus and the more complicated the method the greater will be the experimental error. Since there is no way known as yet of determining the organic matter directly, it becomes necessary to select the method, which gives the most closely concordant results in air of approximately the same degree of purity, or in several duplicate determinations on the same air. The method which constantly gives the lowest results in simultaneous determinations is also probably the one to be preferred as being the most reliable. This method will naturally be the one in which the danger of contamination can be reduced to a minimum, and requires the simplest form of apparatus, and yet affords reasonable certainty that all of the organic matter is absorbed.

Judging from the results obtained in the several series of simultaneous determinations (see Tables XII to XV), it is no easy matter to decide which of the different methods is to be preferred as being the most reliable. Taking all the points into consideration, however, it appears to me that the Remsen absorption tube and the absorbent material recommended by Remsen—freshly ignited granular pumice-stone—affords the most trustworthy results. The absorption tube is small and easily cleansed, and the pumice-stone can be freed from organic matter by prolonged incineration in a platinum crucible. The process of distillation employed in this and several of the other methods is, however, liable to lead to considerable error, especially in inexperienced hands. The amounts of ammonia to be derived from the organic matter in several hundred litres of air are extremely small, so

that without the utmost caution in the entire manipulation the experimental error may exceed several times the amount of ammonia really present. Aside from these difficulties there is also the difficulty of securing absolute freedom of all ammonia in the retort, condenser, and in the receivers, as well as the great difficulty generally experienced in preparing distilled water sufficiently free from ammonia to make its use safe for the purposes required in these methods.

The pumice-stone also affords the most reliable results in the methods depending upon the oxidation of the organic matter in the air by means of permanganate solution. Since, however, the results obtained in this manner are influenced by the presence of other reducing bodies in the air, this cannot be looked upon as being an ideal method.

It is evident that the quantity of organic matter in the air varies from hour to hour and from day to day. As to the source of this organic matter, it may be stated that this will vary constantly with the locality and the nature of its surroundings. The dust of the air is undoubtedly a rich source of ammonia and is also an active reducing agent upon permanganate. The relative proportion of the organic matter in the air that is of a nitrogenous nature seems to be quite large, yet it is evident from the results of analyses that a portion of the organic matter is non-nitrogenous in character. It is probable that a large proportion of the nitrogenous organic matter in the air exists in the form of dust particles arising from vegetable and animal débris, and that the proportion of gaseous, nitrogenous organic matters is much smaller than is commonly supposed, at least in ordinary air; and such as do exist are presumably of the form of amines from putrefactive processes. Such gaseous bodies could occur in large amounts only in the vicinity of excessive quantities of putrefying materials, or of certain manufacturing establishments, as, for instance, soap factories or bone-boiling establishments.

In the opinion of Gray,[16] "the organized nitrogen exists in the air in the form of germs and minute organisms and possibly of minute particles of disintegrated organic matter. The combined nitrogen contained in rain is derived from three sources: the ammonia compounds derived from the decay of animal and vegetable substances and from the combustion of fuel; the organic matter existing in the air; and, lastly, the nitric acid resulting either from the oxidation of ammonia, and probably some of the organic matter, or, from the direct union of atmospheric oxygen and nitrogen under the influence of electrical discharges taking place in the atmosphere."

From the fact, therefore, that the greater portion of the organic matter in the air is in the form of dust particles, and that but a relatively

small proportion of it is usually present in the gaseous form, the method of analysis which will be most likely to present results that possess any degree of accuracy will be the one which abstracts the dust particles most efficiently from the sample of air analyzed. In the second place, the most reliable method will be the one in which the organic matter is converted into ammonia with the least possibility of any considerable experimental error arising from the manipulation. The method which has seemed to me to meet all these indications most satisfactorily is that of Remsen. Here the absorbent material consists of finely granular pumice-stone that has been freshly ignited for twelve to twenty-four hours. This is filled into a small glass absorption tube, twenty centimetres in length, consisting of a narrow portion four centimetres long and three millimetres in internal diameter, and of a wider portion sixteen centimetres long and twelve millimetres in internal diameter. The mouth of this tube is closed by means of perforated rubber cork bearing a short piece of glass tubing through which the air enters. This tube is cleansed by placing it for some hours in a mixture of bichromate of potash, sulphuric acid, and water. It is thoroughly rinsed with twice distilled water, until free of all trace of the cleansing mixture, and wiped on the outside with a clean towel. It is now ready to be filled with the freshly ignited pumice-stone. This is transferred from the plantinum crucible with a clean, porcelain, spoon-shaped spatula. As soon as the pumice has cooled somewhat it is well moistened with twice distilled water, the rubber stopper is put in place, and the narrow portion attached to a gas-meter or aspirator by means of rubber tubing. The moistened granular pumice-stone thus affords an excellent absorbent for the dust particles in the air aspirated through it.

None of the absorbents used in the other methods seem to afford such favorable opportunities for the abstraction of the dust particles in the air. This is especially the case with liquid absorbent materials. The air passes through these in the form of fine bubbles, but under such circumstances the dust particles may also pass with these air bubbles, because they are moistened with considerable difficulty. Neither can the absorbent materials used in the other methods be subjected to such purifying processes as the pumice-stone, which can be heated to redness without injuring its absorbent powers.

Those methods in which the organic matter is determined by estimating the quantity of permanganate reduced by it seem to be less satisfactory in many respects than those in which the organic matter is converted into ammonia. In the first place, such results are always influenced by the reducing action of other bodies in the air besides those of organic nature. In the second place the rate at which many organic

bodies become oxydized by the permanganate is sufficiently slow to escape detection by this process as ordinarily conducted. Finally, the process of determination by boiling with acidulated solution of permanganate of potash and titration with oxalic acid solution is a very delicate one, requiring considerable care and experience to obtain concordant results.

Those methods in which the determination is made with cold permanganate solution, and where the amount of organic matter is estimated colorimetrically, are open to several objections. The permanganate acts quite slowly in cold solution and without any degree of regularity. The estimation colorimetrically, as in the method of Carnelly and Mackie,[17] is a most uncertain process because of the difficulty of detecting slight variations in the tints of permanganate solutions of the strength employed by them, or even of solutions of but half that strength. It appeared to me that the operation was rendered somewhat easier by using a permanganate solution of only one-half the strength recommended by them. The same objections apply to those methods in which cold solutions of permanganate are shaken with successive portions of a sample of air until they are decolorized, as in R. Angus Smith's "air-washing"; and in methods already described in which the permanganate is added slowly to a sample of air in a flask as long as it is being decolorized. Under such conditions the permanganate acts slowly and unsatisfactorily; and there is great difficulty in recognizing the exact point of neutralization since the end-reaction is not sharply defined, and as yet there appears to be no way in which it can be made more definite.

## THE RESULTS OBTAINED IN AIR ANALYSES BY THE DIFFERENT METHODS.

### Method I.

Absorbent material: twice distilled water.

Absorption apparatus: a Pettenkofer absorption tube.

TABLE I.

| No. of experiments. | Date, 1895. | Source of the air aspirated. | Time taken in aspirating. | Amount of air aspirated. | Window. | Mgs. of $NH_3$ in 1 cbm. of air. | |
|---|---|---|---|---|---|---|---|
| | | | | | | Free $NH_3$. | Alb. $NH_3$. |
| 1 | 20-VI | Room | 7 hours | 36.0 L. | Closed | 69.444 mgs. | 458.333 mgs. |
| 2 | 20-VI | Sewer pipe | 7 " | 73.6 " | .... | 47.554 " | 33.967 " |
| 3 | 21-VI | Room | 6½ " | 33.0 " | Closed | 75.757 " | 181.818 " |
| 4 | 21-VI | Sewer pipe | 6½ " | 109.0 " | .... | 27.522 " | 22.935 " |
| 5 | 22-VI | Room | 6 " | 26.0 " | Closed | 0.000 " | 250.000 " |
| 6 | 22-VI | Sewer pipe | 6 " | 84.9 " | .... | 0.000 " | 88.339 " |
| 7 | 24-VI | Room | 7½ " | 122.0 " | Closed | 0.000 " | 0.000 " |

This table shows analyses made of the air of one of the rooms of the laboratory, and of the air of one of the soil pipes at the same time on several successive days, the organic matter being converted into ammonia. The windows of the room were closed on each day. The results obtained from the room-air are uniformly higher than those obtained from the air of the soil pipe. With one exception, the proportion of albuminoid ammonia in the air of the soil pipe is smaller than that of the free ammonia, while in the room-air, with the exception of the last analysis where no ammonia was found, the albuminoid ammonia is far in excess of the free ammonia.

TABLE II.

| No. of experiments. | Date, 1895. | Amount of air aspirated. | Time taken in aspirating. | Source of the air. | With or without dust-filter. | Mgs. of O. consumed for 1 cbm. of air. |
|---|---|---|---|---|---|---|
| 1 | 8-IV | 114.0 L. | 23 hours | Room | Without | 4.3859 mgs. |
| 2 | 8-IV | 38.9 " | 49½ " | Sewer pipe | " | 4.0785 " |
| 3 | 9-IV | 90.0 " | 24¼ " | Room | " | 5.2884 " |
| 4 | 11-IV | 128.0 " | 31 " | " | " | 4.7701 " |
| 5 | 11-IV | 246.7 " | 31 " | Sewer pipe | " | 0.5253 " |
| 6 | 15-IV | 243.0 " | 46½ " | Room | " | 0.7920 " |
| 7 | 15-IV | 191.8 " | 46½ " | Sewer pipe | " | 0.5874 " |
| 8 | 18-IV | 220.0 " | 50½ " | Room | " | 0.6114 " |
| 9 | 18-IV | 209.4 " | 50½ " | Sewer pipe | " | 0.3903 " |
| 10 | 20-IV | 285.0 " | 50 " | Room | " | 0.2193 " |
| 11 | 20-IV | 141.5 " | 50¼ " | Sewer pipe | " | 0.2718 " |
| 12 | 22-IV | 198.0 " | 49¼ " | Room | With | 0.4613 " |
| 13 | 22-IV | 117.4 " | 49¼ " | Sewer pipe | Without | 0.6876 " |
| 14 | 25-IV | 296.0 " | 49 " | Room | " | 0.2484 " |
| 15 | 25-IV | 191.8 " | 49 " | Sewer pipe | " | 0.4600 " |
| 16 | 27-IV | 314.0 " | 48¾ " | Room | With | 0.3434 " |
| 17 | 27-IV | 90.0 " | 48¾ " | Sewer pipe | Without | 0.6535 " |

This table shows analyses made of air taken from the same sources as those recorded in Table I, but in this instance the quantity of organic matter is estimated by its reducing action on permanganate instead of being converted into ammonia. In two of the analyses of the room-air a dust-filter had been placed before the absorption apparatus, but since no analyses were made on the same day without the use of a dust-filter the results obtained afford no information as to the effects of such a dust-filter on the results obtained. The results obtained without the use of a dust-filter, on succeeding days, are in some instances even more variant than those with, and without, the use of the dust filter. No suggestion can be offered to explain the very high results obtained in the first four analyses. No uniform relation can be determined between the relative amounts of organic matter in the room-air and that of the soil pipe in the results obtained by this method, as seemed to be the case in the results recorded in Table I.

## Method II.

Absorbent materials: (a) purified glass-wool, (b) acidulated permanganate solution.

Absorption apparatus: two small Erlenmeyer flasks, connected by rubber tubing; modification of Uffelmann's apparatus.

TABLE III.

| No. of experiment. | Date, 1895. | Amount of air aspirated. | Time taken in aspirating. | Source of the air. | Window. | Mgs. of O consumed for 1 cbm. of air. | |
|---|---|---|---|---|---|---|---|
| | | | | | | Gaseous form. | Dust-form. |
| 1 | 7-VI | 30.0 L. | 1 hour | Room | Closed | 0.31746 mgs | 3.80952 mgs |
| 2 | 7-VI | 25.0 " | 1 " | " | " | 13.33333 " | 2.09523 " |
| 3 | 8-VI | 30.0 " | 1 " | " | " | 0.63492 " | 0.63492 " |
| 4 | 10-VI | 27.0 " | 1 " | " | " | 0.35273 " | 0.17637 " |
| 5 | 20-VI | 7.3 " | 2¼ hrs. | " | " | 19.56947 " | 19.56947 " |
| 6 | 21-VI | 8.8 " | 5 " | " | " | 54.11255 " | 16.23376 " |
| 7 | 22-VI | 6.7 " | 3¼ " | " | " | 0.00000 " | 21.32196 " |
| 8 | 24-VI | 7.5 " | 5¼ " | " | Open | 19.04761 " | 6.39420 " |
| 9 | 24-VI | 8.3 " | 5¾ " | " | " | 5.73723 " | 34.42340 " |
| 10 | 26-VI | 5.5 " | 4¼ " | " | " | 17.65224 " | |
| 11 | 26-VI | 8.0 " | 3¾ " | " | " | 8.82612 " | |
| 12 | 26-VI | 10.0 " | 3¾ " | " | " | 19.41747 " | 72.81553 " |
| 13 | 2-VII | 8.4 " | 6¼ " | " | Closed | 5.75109 " | 11.50218 " |
| 14 | 2-VII | 8.25 " | 5¼ " | " | " | 5.75109 " | |
| 15 | 2-VII | 12.1 " | 5¼ " | " | " | 5.75109 " | 34.50654 " |
| 16 | 3-VII | 17.3 " | 5¼ " | " | Open | 19.64195 " | 15.67989 " |
| 17 | 3-VII | 8.0 " | 4¼ " | " | " | 33.90776 " | 79.11812 " |
| 18 | 3-VII | 8.4 " | 5¼ " | " | " | 43.05748 " | 40.45307 " |
| 19 | 8-VII | 7.6 " | 6¼ " | " | " | 25.42588 " | 44.49529 " |
| 20 | 8-VII | 8.05 " | 6¼ " | " | " | 6.00114 " | 48.00912 " |
| 21 | 8-VII | 10.2 " | 6 " | " | " | 4.73619 " | 18.94476 " |

This table shows analyses made on room-air, mostly in duplicate and triplicate, with separate estimations of the gaseous and of the dust-form of organic matter. The results obtained in simultaneous determinations on the same air show a marked variation. This variation in the results seems to be intimately connected with the quantity of air that was aspirated through each apparatus; the greater the quantity of air aspirated the smaller the relative proportion of organic matter found, both as to the gaseous and the dust-form of organic matter. There is no indication from the results obtained of any definite relation between the quantity of organic matter in gaseous form to that in the form of dust.

The objections to this method are that the amounts of the absorbent materials are quite small and consequently incapable of absorbing any material portion of the organic matter from the air passed through them. The small quantity of absorbent material also necessitates the aspiration of the air in very slow current. The results obtained are quite variant

in simultaneous determinations on the same air, and are influenced to a marked degree by the quantity of air used. Another objection is the difficulty with which the glass-wool is boiled with the permanganate on account of the bumping and spirting that take place even though the heat applied is barely sufficient to keep the fluid at the boiling point. With the utmost care possible several of the determinations of the dust-form of organic matter were so vitiated from this cause as to necessitate their omission from the table.

For these different reasons I consider this to be a totally unreliable and unsatisfactory method, and especially so with regard to the quantitative determination of the relative proportions of organic matter in air in its two forms, the gaseous and dust-form. In my hands it has failed utterly to differentiate between these two forms of organic matter.

## Method III.

Absorbent material: freshly ignited, finely granular pumice-stone.

Absorption apparatus: a small glass tube, twenty centimetres in length, consisting of a narrow portion four centimetres long and three millimetres in its internal diameter, and an expanded portion sixteen centimetres long and twelve millimetres in its internal diameter, similar in size and form to the absorption tube used by Remsen and by Abbott in their experiments.

TABLE IV.

| No. of experiment. | Date, 1895. | Amount of air aspirated. | Time taken in aspirating. | Source of the air. | Mgs. of $NH_3$ in 1 cbm. of air. | |
|---|---|---|---|---|---|---|
| | | | | | Free $NH_3$. | Alb. $NH_3$. |
| 1 | 6-III | 214.0 L | 3 hrs | External | 2.3360 mgs | 9.3450 mgs |
| 2 | 7-III | 386.0 " | 4 " | " | 7.7430 " | 1.2950 " |
| 3 | 7-III | 340.0 " | 3½ " | " | 1.4705 " | 4.4110 " |
| 4 | 8-III | 343.0 " | 3½ " | " | 1.4570 " | 2.9150 " |
| 5 | 8-III | 336.0 " | 3½ " | Room | 23.8095 " | 29.7610 " |
| 6 | 9-III | 386.0 " | 4 " | External | 10.5260 " | 13.1570 " |
| 7 | 11-III | 393.0 " | 4 " | " | 10.1770 " | 12.7220 " |
| 8 | 12-III | 364.0 " | 3¾ " | Room | 19.2300 " | 27.4720 " |
| 9 | 12-III | 295.0 " | 3 " | External | 13.5590 " | 84.7450 " |
| 10 | 13-III | 293.0 " | 3 " | " | 0.0000 " | 102.3880 " |
| 11 | 13-III | 310.0 " | 3 " | Room | 0.0000 " | 32.2580 " |
| 12 | 14-III | 370.0 " | 3¾ " | External | 0.0000 " | 10.8100 " |
| 13 | 14-III | 820.7 " | 4 " | Sewer Pipe | 10.9660 " | 8.5290 " |
| 14 | 15-III | 741.5 " | 3 " | " | 25.6230 " | 9.4400 " |
| 15 | 15-III | 300.0 " | 3 " | External | 0.0000 " | 3.3333 " |
| 16 | 16-III | 1533.8 " | 5 " | Sewer Pipe | 4.5660 " | 3.9111 " |
| 17 | 16-III | 330.0 " | 3½ " | Room | 12.1210 " | 9.0909 " |
| 18 | 16-III | 340.0 " | 3½ " | External | 1.4705 " | 1.4705 " |
| 19 | 18-III | 390.0 " | 4 " | " | 0.0000 " | 5.1280 " |
| 20 | 18-III | 1075.4 " | 3½ " | Sewer Pipe | 21.8520 " | 13.4830 " |
| 21 | 19-III | 1971.1 " | 6¾ " | " | 6.0870 " | 4.5650 " |
| 22 | 19-III | 556.0 " | 6¾ " | External | 0.9000 " | 3.5970 " |
| 23 | 20-III | 1282.5 " | 4¼ " | Sewer Pipe | 6.2380 " | 0.7799 " |

This table shows analyses of the room-air and of the soil pipe, and also of the external air, with the organic matter estimated as ammonia. In this table the greater proportion of free ammonia as compared with albuminoid ammonia in the air of the soil pipe is also shown, as in Table I; while in the majority of the analyses of room-air and of the external air the proportion of albuminoid ammonia is again greater than the free ammonia, as was shown by the results in Table I.

TABLE V.

| No. of exp. | Date, 1895. | Hour of day. | Source of the air. | Atmospheric conditions. | | | | Mgs. of $NH_3$ in 1 cbm. of air. | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Clouds. | Tempt. | Bar. | Wind. | Free $NH_3$ | Alb. $NH_3$. |
| | | | | | | mm. | | mgs. | mgs. |
| 1 | 6-III | 10.00 a.m. | External | Part Cloudy | 5.5° C | 775.3 | S. E. | 2.336 | 9.345 |
| 2 | 7-III | 9.50 " | " | Cloudy | 8.5 " | 768.0 | S. W. | 7.743 | 1.295 |
| 3 | 7-III | 2.00 p.m. | " | Raining | 12.0 " | 764.2 | E. | 1.470 | 4.411 |
| 4 | 8-III | 10.00 a.m. | " | Cloudy | 7.5 " | 757.1 | N. E. | 1.457 | 2.915 |
| 5 | 8-III | 2.00 p.m. | Room | " | 8.5 " / 19.5 " | 754.7 | W. | 23.8095 | 29.761 |
| 6 | 9-III | 11.45 a.m. | External | Light Snow | −0.5 " | 756.3 | N. W. | 10.526 | 13.157 |
| 7 | 11-III | 12.10 p.m. | " | Snowing | 0.0 " | 769.1 | N. E. | 10.177 | 12.722 |
| 8 | 12-III | 10.00 a.m. | Room | Cloudy / Misty | 2.0 " / 19.8 " | 767.6 | N. E. | 19.230 | 27.472 |
| 9 | 12-III | 1.45 p.m. | External | Foggy | 3.0 " | 767.3 | E. | 13.559 | 84.745 |
| 10 | 13-III | 11.00 a.m. | " | Cloudy | 8.0 " | 766.5 | S. E. | 0.000 | 102.388 |
| 11 | 13-III | 2.00 p.m. | Room | " | 8.5 " / 20.5 " | 764.1 | S. E. | 0.000 | 32.258 |
| 12 | 14-III | 11.15 a.m. | External | Clear | 3.5 " | 764.8 | N. W. | 0.000 | 10.810 |
| 15 | 15-III | 11.15 " | " | Raining | −3.0 " | 766.0 | N.E | 0.000 | 3.333 |
| 17 | 16-III | 9.30 " | Room | Clear | 0.0 " / 18.0 " | 755.8 | N. W. | 12.121 | 9.0909 |
| 18 | 16-III | 1.00 p.m. | External | " | −0.8 " | 756.5 | N. W. | 1.470 | 1.4705 |
| 19 | 18-III | 11.45 a.m. | " | " | +5.5 " | 759.8 | N. W. | 0.000 | 5.128 |
| 22 | 19-III | 12.15 p.m. | " | Cloudy | 4.0 " | 763.2 | N.E. | 0.900 | 3.597 |

This table, containing the determinations of organic matter in room-air and in external air which form a part of Table IV, shows the atmospherie conditions prevailing at the time the analyses were made. The data as presented here show no marked variations in the quantity of organic matter in external air as the result of the atmospheric conditions. The most marked influence noticeable is the gradual decrease in the quantity of ammonia during several days of rain, snow, and fog; and also but a slight increase during the clear days immediately following that period. The season of the year at which these experiments were made is also most probably that in which the atmospheric influences on the quantity of organic matter in air are least effective. The amount of moisture in the soil at this season is sufficient to prevent the rise of large quantities of dust. The quantity of organic matter in

the room-air was found to be constantly higher than that in the external air.

TABLE VI.

| No. of experiment. | Date, 1895. | Amt. of air aspirated. | Time taken in aspirating. | Source of the air. | Mgs. of O consumed for 1 cbm. of air. |
|---|---|---|---|---|---|
| 1 | 15-III | 196.0 L. | 2 hours | External | 0.0000 mgs. |
| 2 | 20-III | 418.0 " | 4¼ " | " | 0.1955 " |
| 3 | 21-III | 698.0 " | 7 " | " | 0.0413 " |
| 4 | 21-III | 1429.0 " | 4½ " | Sewer pipe | 0.0000 " |
| 5 | 22-III | 598.0 " | 6 " | External | 0.0000 " |
| 6 | 22-III | 1174.5 " | 4¼ " | Sewer pipe | 0.1252 " |
| 7 | 23-III | 1938.5 " | 6½ " | " | 0.1240 " |
| 8 | 23-III | 660.0 " | 6¾ " | Room | 0.0000 " |
| 9 | 25-III | 1471.6 " | 5 " | Sewer pipe | 0.0000 " |
| 10 | 25-III | 623.0 " | 5½ " | Room | 0.0077 " |
| 11 | 4-IV | 576.0 " | 6½ " | External | 0.0000 " |
| 12 | 4-IV | 176.6 " | 6¼ " | Sewer pipe | 1.3600 " |
| 13 | 5-IV | 888.0 " | 9 " | External | 0.0054 " |
| 14 | 5-IV | 2547.0 " | 9 " | Sewer pipe | 0.0000 " |

This table shows analyses made on room-air, external air, and the air of the soil pipe with the quantity of organic matter estimated from its action in reducing permanganate. The results obtained show no uniform relations in analyses of air from the same source on succeeding days. In a number of the determinations there was entire absence of any reducing action, and since it is improbable that there is at any time no organic matter in air drawn from such sources as these samples were taken, it is evident that this is not a reliable method for the determination of organic matter in air.

## Method IV.

Absorbent material: a $\frac{n}{1000}$ solution of permanganate of potash, as employed by Carnelley and Mackie.

Absorption apparatus: flasks of about four litres capacity.

TABLE VII.

| No. of experiment. | Date, 1895. | Amt. of air used. | Source of the air. | Windows. | Mgs. of O consumed for 1 cbm. of air. |
|---|---|---|---|---|---|
| 1 | 9-V | 3.885 L. | Room | Open | 12.3552 mgs. |
| 2 | 9-V | 3.910 " | " | " | 12.2762 " |
| 3 | 10-V | 3.885 " | " | " | 12.3552 " |
| 4 | 10-V | 3.910 " | " | " | 12.2762 " |
| 5 | 11-V | 3.885 " | " | " | 10.3293 " |
| 6 | 11-V | 3.910 " | " | " | 10.2301 " |
| 7 | 11-V | 3.885 " | " | " | 12.3552 " |
| 8 | 11-V | 3.910 " | " | " | 12.2762 " |
| 9 | 13-V | 3.885 " | " | Closed | 28.8288 " |
| 10 | 13-V | 3.910 " | " | " | 28.6444 " |
| 11 | 15-V | 3.885 " | " | " | 8.2368 " |
| 12 | 18-V | 3.885 " | " | " | 10.3293 " |
| 13 | 18-V | 3.910 " | " | " | 6.9565 " |
| 14 | 24-V | 3.885 " | " | " | 12.3552 " |
| 15 | 24-V | 3.910 " | " | " | 12.2762 " |
| 16 | 27-V | 3.885 " | " | " | 8.2368 " |
| 17 | 27-V | 3.910 " | " | " | 8.1841 " |
| 18 | 29-V | 3.885 " | " | Open | 8.2368 " |
| 19 | 29-V | 3.910 " | " | " | 6.1381 " |
| 20 | 31-V | 3.885 " | " | " | 8.2368 " |
| 21 | 31-V | 3.910 " | " | " | 8.1841 " |
| 22 | 1-VI | 3.885 " | " | " | 24.7104 " |
| 23 | 1-VI | 3.910 " | " | " | 16.3682 " |
| 24 | 3-VI | 3.885 " | " | " | 8.2368 " |
| 25 | 3-VI | 3.910 " | " | " | 2.0460 " |
| 26 | 4-VI | 3.885 " | " | Closed | 16.4736 " |
| 27 | 4-VI | 3.910 " | " | " | 8.1841 " |

This table shows analyses in which the organic matter is determined colorimetrically by comparing a portion of the permanganate that has been exposed to the air with the tint of an equal amount of fresh permanganate solution.

While the results show marked variations in the amount of organic matter in the air in a few of the determinations, the results cannot be taken as showing with any degree of accuracy the amount of organic matter that was really present. The objections to this method have already been considered elsewhere at sufficient length to require any further remarks. It is probably true, as claimed by Carnelley and Mackie, that for a rough estimate this method is not without some value. The principal points in its favor are the fact that it is portable and may thus serve to analyze air at a distance from the laboratory, and that it requires quite simple apparatus for its operation.

TABLE VIII.

| No. of experiment. | Date, 1895. | Amt. of air used. | Source of the air. | Windows. | Atmospheric conditions. | Mgs. of O consumed for 1 cbm. of air. |
|---|---|---|---|---|---|---|
| 1 | 2-VII | 3.968 L. | Room. | Open | Clear | 12.096 mgs. |
| 2 | 10-VII | 3.968 " | " | " | " | |
| 3 | 26-VII | 3.968 " | " | " | " | 5.040 " |
| 4 | 26-VII | 3.910 " | " | " | " | 5.112 " |
| 5 | 16-VIII | 3.968 " | " | " | " | 6.048 " |
| 6 | 16-VIII | 3.910 " | " | " | " | 6.112 " |
| 7 | 20-VIII | 3.968 " | " | Closed | " | 4.032 " |
| 8 | 20-VIII | 3.910 " | " | " | " | 4.092 " |
| 9 | 26-VIII | 3.968 " | " | Open | " | 3.025 " |
| 10 | 26-VIII | 3.910 " | " | " | " | 3.069 " |
| 11 | 28-VIII | 3.968 " | " | " | Partly Cloudy | 2.016 " |
| 12 | 28-VIII | 3.910 " | " | " | " " | 2.046 " |
| 13 | 30-VIII | 3.968 " | " | " | Cloudy | 3.025 " |
| 14 | 30-VIII | 3.910 " | " | " | " | 3.069 " |
| 15 | 2-IX | 3.968 " | " | " | Clear | 4.032 " |
| 16 | 2-IX | 3.910 " | " | " | " | 4.092 " |

This table shows analyses made in which the organic matter is determined from the quantity of $\frac{n}{2000}$ permanganate solution that is decolorized when shaken with a sample of air in a flask. The results obtained with this method are only an approximate indication of the amount of organic matter in a sample of air. It is open to the same criticisms as the method of Carnelley and Mackie, and appears to give results that are equally as good as those obtained by their method. The points in its favor are the same as those claimed for their method, while it is probably easier to operate and requires less apparatus.

## Method V.

Absorbent materials: (a) $\frac{n}{10}$ sulphuric acid; (b) twice distilled water.
Absorption apparatus: a Pettenkofer absorption tube.

TABLE IX.

| No. of experiment. | Date, 1895. | Amt. of air aspirated. | Time taken in aspirating. | Source of the air. | Mgs. of $NH_3$ in 1 cbm. of air. |
|---|---|---|---|---|---|
| 1 | 13-V | 342.0 L. | $26\frac{1}{4}$ hours. | Room | 0.000 mgs. |
| 2 | 13-V | 55.0 " | $26\frac{1}{4}$ " | Sewer pipe | 37.090 " |
| 3 | 15-V | 191.0 " | 26 " | Room | 0.000 " |
| 4 | 15-V | 44.0 " | $46\frac{1}{4}$ " | Sewer pipe | 30.909 " |
| 5 | 17-V | 232.0 " | 25 " | Room | 0.000 " |
| 6 | 17-V | 67.9 " | 25 " | Sewer pipe | 25.029 " |

This table shows analyses made of room-air and the air of a soil pipe in which the quantity of ammonia was determined directly. The air was aspirated through $\frac{n}{10}$ sulphuric acid and the amount of free acid

remaining in solution then estimated by titration with $\frac{n}{10}$ ammonium hydroxid. The results obtained show the absence of ammonia in the room-air, while the quantity of ammonia in the air of the soil pipe appears to be of fairly constant proportions. This method appears to be sufficiently reliable for general use. The importance of the results obtained rests mainly upon the fact that they indicate to what extent the ammonia in the air, under certain conditions, may become a factor in the determination of organic matter in air with any of the methods in use.

TABLE X.

| No. of experiment. | Date, 1895. | Amount of air aspirated. | Time taken in aspirating. | Source of the air. | With or without dust-filter. | Mgs. of $NH_3$ in 1 cbm. of air. |
|---|---|---|---|---|---|---|
| 1 | 8-VII | 110.5 L. | 7 hrs. | Room | Without | 0.0000 mgs. |
| 2 | 8-VII | 118.3 " | 7 " | Sewer pipe | " | 0.8450 " |
| 3 | 23-X | 8.25 " | 5 " | Room | " | 0.3030 " |
| 4 | 24-X | 8.0 " | $2\frac{5}{6}$ " | " | " | 0.2500 " |
| 5 | 25-X | 8.0 " | $4\frac{1}{2}$ " | " | With | 0.0000 " |
| 6 | 25-X | 8.0 " | $4\frac{1}{4}$ " | " | Without | 0.1875 " |
| 7 | 7-XI | 119.4 " | $22\frac{1}{3}$ " | " | With | 0.0000 " |
| 8 | 7-XI | 73.0 " | $22\frac{1}{3}$ " | " | Without | 0.0000 " |
| 9 | 8-XI | 68.2 " | 24 " | " | With | 0.0000 " |
| 10 | 8-XI | 57.5 " | 24 " | " | Without | 0.0000 " |
| 11 | 9-XI | 204.9 " | 24 " | " | With | 0.0360 " |
| 12 | 9-XI | 138.75 " | 24 " | " | Without | 0.0029 " |
| 13 | 10-XI | 131.5 " | $23\frac{3}{4}$ " | " | With | 0.0000 " |
| 14 | 10-XI | 88.25 " | $23\frac{3}{4}$ " | " | Without | 0.0056 " |
| 15 | 11-XI | 186.2 " | $23\frac{1}{2}$ " | " | With | 0.0000 " |
| 16 | 11-XI | 212.0 " | $23\frac{1}{2}$ " | " | Without | 0.00235 " |
| 17 | 12-XI | 82.0 " | $23\frac{1}{4}$ " | " | With | 0.0000 " |
| 18 | 12-XI | 192.5 " | $23\frac{1}{4}$ " | " | Without | 0.0000 " |
| 19 | 13-XI | 157.6 " | $25\frac{1}{4}$ " | " | With | 0.0000 " |
| 20 | 13-XI | 109.0 " | $25\frac{1}{4}$ " | " | Without | 0.0000 " |

This table shows analyses made by aspirating the air through 100 c. c. of twice distilled water, and testing with Nessler's reagent; thus estimating directly the amount of ammonia in the air. Usually two simultaneous tests were made on the same air, the one with, and the other without, the attachment of a dust-filter. There appears to be some evidence of the direct influence of the dust of the air on the results obtained in this manner, though at times no ammonia was found even without the use of the dust-filter. At all times the quantities of ammonia found were quite small.

## Method VI.

Absorbent material: a $\frac{n}{10}$ solution of iodine.

Absorption apparatus: a Pettenkofer absorption tube.

TABLE XI.

| No. of experiment. | Date, 1895. | Amount of air aspirated. | Time taken in aspirating. | Source of the air. | Mgs. of $H_2S$ in 1 cbm. of air. | Mgs. of $SO_2$ in 1 cbm. of air. |
|---|---|---|---|---|---|---|
| 1 | 29-IV | 82.0 L. | 21½ hrs. | Sewer pipe | 76.70 mgs. | 144.39 mgs. |
| 2 | 30-IV | 191.8 " | 48 " | " | 24.81 " | 46.71 " |
| 3 | 1-V | 212.25 " | 22 " | " | 30.43 " | 57.29 " |
| 4 | 2-V | 238.0 " | 21¾ " | Room | 26.84 " | 50.52 " |
| 5 | 2-V | 235.7 " | 23¼ " | Sewer pipe | 29.21 " | 54.98 " |
| 6 | 3-V | 183.0 " | 21¼ " | Room | 30.65 " | 57.70 " |
| 7 | 3-V | 123.0 " | 21¼ " | Sewer pipe | 33.88 " | 63.79 " |
| 8 | 4-V | 128.765 " | 69¾ " | " | 64.69 " | 121.78 " |

This table shows analyses made to determine the quantities of other reducing bodies in the air besides those of organic nature. The results obtained are expressed as sulphuretted hydrogen in the one column, and as sulphurous acid in the other. Both of these react on the iodine in a similar manner, and it is impossible to separate them from each other in these analyses. The value of these results lies in the fact that they show the extent to which the results obtained as organic oxidizable matter with some of the methods are influenced by these reducing bodies when present in the air.

## SIMULTANEOUS DETERMINATIONS.

In order to ascertain the relative value of the results obtained by the different methods, it was deemed advisable to make simultaneous determinations on the same air with several of the methods. Such a series of determinations should afford some indication as to which of the methods is probably the most reliable from the uniformity of the results which they give us.

TABLE XII.

| No. of experiment. | Date, 1895. | Method. | Amount of air used. | Time taken in aspirating. | Source of the air. | Mgs. of O consumed from 1 cbm. of air. | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | Gaseous form. | Dust-form. | Total. |
| | | | | | | mgs. | mgs. | mgs. |
| 1 | 10-X | III-b | 136.5 L. | 3⅔ hrs. | Room | | | 0.22916 |
| 2 | 10-X | II-a | 8.0 " | 3⅔ " | " | 5.98728 | 14.66275 | 20.65403 |
| 3 | 10-X | I-b | 8.0 " | 2¼ " | " | | | 14.66275 |
| 4 | 11-X | III-b | 172.75 " | 5 " | " | | | 0.63043 |
| 5 | 11-X | II-a | 6.33 " | 5⅙ " | " | 3.12827 | 15.64137 | 18.76964 |
| 6 | 11-X | I-b | 8.0 " | 4⅙ " | " | | | 15.71782 |
| 7 | 12-X | III-b | 20.0 " | 3½ " | " | | | 10.09085 |
| 8 | 12-X | II-a | 7.625 " | 3¾ " | " | 11.58682 | 17.57121 | 29.15803 |
| 9 | 12-X | I-b | 7.5 " | 3¾ " | " | | | 8.67313 |
| 10 | 14-X | III-b | 95.0 " | 4⅓ " | " | | | 0.87462 |
| 11 | 14-X | II-a | 7.25 " | 5½ " | " | 7.01115 | 21.30313 | 28.31428 |
| 12 | 10-X | I-b | 7.5 " | 4½ " | " | | | 14.72792 |

The marked variation in the total amounts of organic matter found in simultaneous determinations with these three methods shows that no reliance can be placed on the results obtained by at least two of these methods. The nearly uniformly low results obtained with method III-b indicate that this method is the preferable one of the three entering into this experiment.

TABLE XIII.

| No. of experiment. | Date, 1896. | Source of the air. | Amount of air aspirated. | Time taken in aspirating. | With or without dust-filter. | Method. | Mgs. of O consumed for 1 cbm. of air. |
|---|---|---|---|---|---|---|---|
| 1 | 4-III | Room | 52.0 L. | 6⅔ hrs. | With | III-b | 3.8658 mgs. |
| 2 | 4-III | " | 72.7 " | 6⅔ " | Without | III-b | 7.2145 " |
| 3 | 4-III | " | 13.1 " | 6⅔ " | With | I-b | 8.2900 " |
| 4 | 4-III | " | 15.4 " | 6⅔ " | Without | I-b | 6.3661 " |
| 5 | 5-III | " | 158.0 " | 7 " | With | III-b | 1.7684 " |
| 6 | 5-III | " | 113.2 " | 7 " | Without | III-b | 3.6374 " |
| 7 | 5-III | " | 13.75 " | 7 " | With | I-b | 35.6506 " |
| 8 | 5-III | " | 13.3 " | 7 " | Without | I-b | 20.6398 " |

The results obtained with method III-b show a constant influence from the dust-filter attached, but those obtained with method I-b fail to show such an influence; in fact, the results are invariably higher, from some unexplained cause, in the determinations with the dust-filter than in those in which it was not used. It seems, therefore, that method I-b is not reliable, even with the utmost care possible.

TABLE XIV.

| No. of experiment. | Date, 1896. | Amount of air aspirated. | Time taken in aspirating. | Source of the air. | With or without dust-filter. | Method. | Mgs. of $NH_3$ in 1 cbm. of air. | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | Free $NH_3$ | Alb. $NH_3$ |
| 1 | 6-I | 434.5 L. | 23½ h. | Room | With | III-a | 0.0092 mgs. | 0.0103 mgs. |
| 2 | 6-I | 1051.9 " | 23½ " | " | Without | " | 0.0294 " | 0.0175 " |
| 3 | 7-I | 437.0 " | 25 " | " | With | " | 0.0137 " | 0.0034 " |
| 4 | 7-I | 1033.5 " | 25 " | " | Without | " | 0.0387 " | 0.0062 " |
| 5 | 9-I | 838.0 " | 25 " | " | With | " | 0.0095 " | 0.0053 " |
| 6 | 29-I | 1158.6 " | 25 " | " | Without | " | 0.0232 " | 0.0081 " |
| 7 | 25-II | 698.5 " | 24½ " | " | With | " | 0.0114 " | 0.0078 " |
| 8 | 25-II | 766.9 " | 24½ " | " | Without | " | 0.0182 " | 0.0071 " |
| 9 | 26-II | 686.5 " | 24½ " | " | With | " | 0.0182 " | 0.0043 " |
| 10 | 26-II | 758.7 " | 24½ " | " | Without | " | 0.0237 " | 0.0158 " |
| 11 | 27-II | 727.5 " | 24 " | " | With | " | 0.0343 " | 0.0013 " |
| 12 | 27-II | 819.8 " | 24 " | " | Without | " | 0.0536 " | 0.0030 " |
| 13 | 28-II | 480.0 " | 25¾ " | " | With | " | 0.0156 " | 0.0041 " |
| 14 | 28-II | 873.9 " | 25¼ " | " | Without | " | 0.0583 " | 0.0005 " |

This table shows the results obtained in a series of simultaneous determinations with Method III-a, with and without the use of a dust-

filter. It will be noted that in each instance the free ammonia is lower with than without the dust-filter, and only in two instances is the albuminoid ammonia lower without than with the use of the dust-filter. The total ammonia is, however, constantly lower with than without the use of the dust-filter, so that there is strong evidence that the dust in the air is the source of a large part, if not all, of the organic matter. It is probable that the dust-filter of asbestos failed to filter out the finer dust particles, and it is from these we still get the reaction of ammonia in these determinations with the use of the dust-filter.

TABLE XV.

| No. of experiment. | Date, 1895. | Amount of air used. | Time taken in aspirating. | Source of the air. | With or without dust-filter. | Method. | Mgs. of $NH_3$ in 1 cbm. of air. | | Mgs. of O consumed for 1 cbm. |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Free $NH_3$ | Alb. $NH_3$ | |
| | | | | | | | mgs. | mgs. | mgs. |
| 1 | 15-X | 7.25 L. | $4\frac{3}{4}$ h. | Room | Without | I-a | 0.0052 | 0.0317 | |
| 2 | 15-X | 192.0 " | $4\frac{3}{4}$ " | " | " | III-a | 0.3448 | 0.6896 | |
| 3 | 16-X | 8.0 " | $4\frac{2}{3}$ " | " | " | I-a | 0.1250 | 0.7625 | |
| 4 | 16-X | 8.0 " | $4\frac{5}{6}$ " | " | " | III-a | 0.0625 | 0.5000 | |
| 5 | 21-X | 7.5 " | 6 " | " | " | I-a | 0.0666 | 0.0133 | |
| 6 | 21-X | 7.25 " | 6 " | " | " | III-a | 0.0000 | 0.0000 | |
| | 1896. | | | | | | | | |
| 7 | 12-III | 41.0 " | $6\frac{3}{4}$ " | " | With | III-a | 0.0000 | 0.0268 | |
| 8 | 12-III | 38.7 " | $6\frac{3}{4}$ " | " | Without | III-a | 0.0129 | 0.0516 | |
| 9 | 12-III | 15.75 " | $6\frac{3}{4}$ " | " | With | I-a | 0.0000 | 0.0666 | |
| 10 | 12-III | 14.1 " | $6\frac{3}{4}$ " | " | Without | I-a | 0.0000 | 0.0422 | |
| 11 | 12-III | 3.775 " | .... | " | " | IV-a | | | 3.1788 |
| 12 | 12-III | 3.83 " | ... | " | " | IV-a | | | 3.1331 |
| 13 | 12-III | 3.754 " | ... | " | " | IV-b | | | 2.6638 |
| 14 | 13-III | 3.775 " | .... | " | " | IV-a | | | 8.4765 |
| 15 | 13-III | 3.83 " | .... | " | " | IV-a | | | 8.3550 |
| 16 | 13-III | 3.754 " | .... | " | " | IV-b | | | 4.2621 |
| 17 | 13-III | 38.0 " | 6 " | " | With | III-a | 0.0000 | 0.1184 | |
| 18 | 13-III | 82.9 " | 6 " | " | Without | III-a | 0.0240 | 0.0904 | |
| 19 | 13-III | 7.85 " | 6 " | " | With | I-a | 0.0000 | 1.0191 | |
| 20 | 13-III | 7.75 " | 6 " | " | Without | I-a | 0.0000 | 1.2903 | |

The results in this table seem to indicate that the amount of organic matter, as shown by Methods IV-a and b, bears some relation to the amount of ammonia as shown by Methods I and III. The results obtained with Method III are lower as a rule than those obtained with Method I. The influence of the dust-filter on the quantity of organic matter recovered from the absorbent material is most marked with Method III.

## CONCLUSIONS.

1. The quantity of organic matter bears an intimate relation to the amount of dust floating in the air. It is probable that the gaseous

organic matter forms but an exceedingly small proportion of the total organic matter.

2. The attachment of a dust-filter of asbestos to the absorption apparatus produces results that are constantly lower than those obtained without the dust-filter.

3. The most reliable method for the estimation of organic matter in air is that known as Remsen's method, and is called Method III-a in this research. The pumice-stone seems to be the best form of absorbent material because it can be thoroughly cleansed by heat without changing its condition or usefulness.

4. Those methods which determine the organic matter from its reducing action on permanganate do not seem to afford as satisfactory results as those in which the organic matter is estimated as ammonia.

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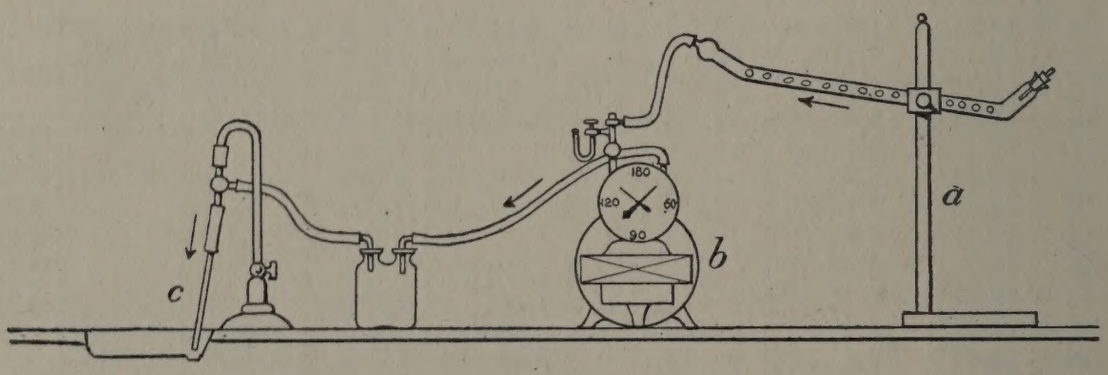


Fig. 1.—Apparatus used with Methods I, V, and VI. This apparatus consists of: *a*—a stative which supports the Pettenkofer absorption tube containing the absorbent material; *b*—the gas-meter which measures the volume of air aspirated through the apparatus; and *c*—a Chapman water pump, by means of which a slow, steady current of air is maintained through the apparatus.

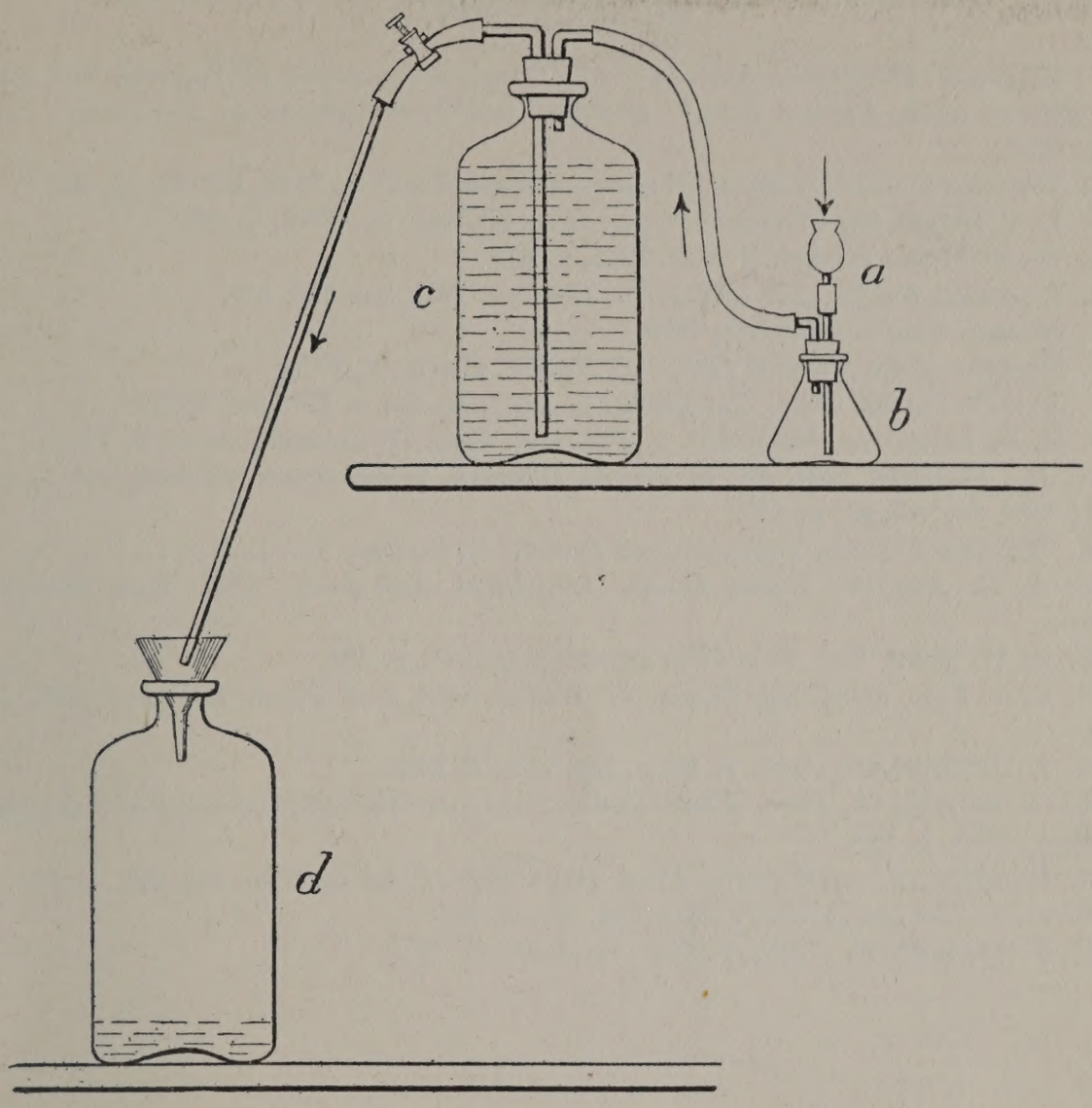


Fig. 2.—Apparatus used in Method II. It consists of : *a*—a small globe-shaped glass tube containing the glass-wool absorbent for the dust in the air ; *b*—a small Erlenmeyer flask containing the acidulated permanganate solution to absorb the gaseous organic matter ; *c*—a graduated flask of eight litres capacity, which serves as an aspirator ; and *d*—another eight-litre flask into which the water drains from the aspirator.

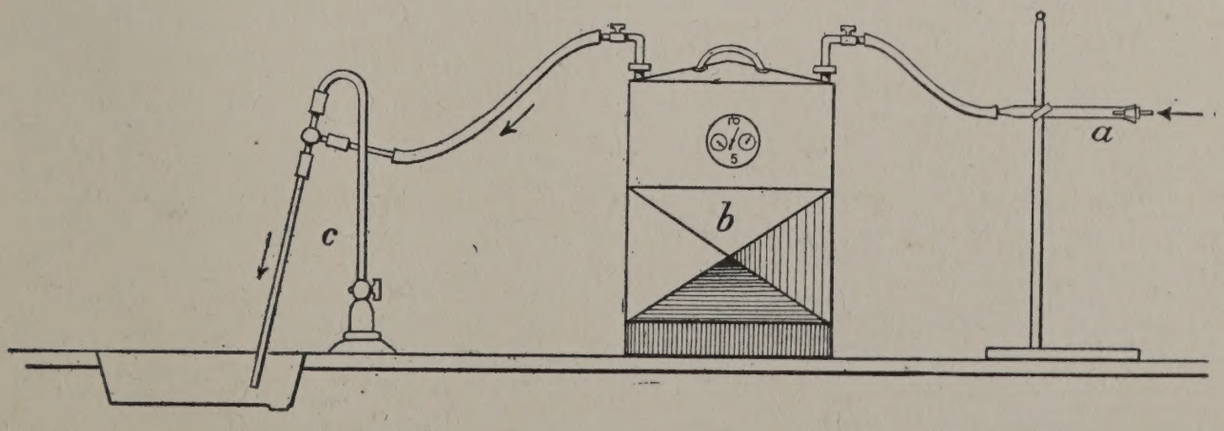


Fig. 3.—Apparatus used with Method III. It consists of : *a*—a small glass tube, twenty centimetres in length, consisting of a narrow portion four centimetres long and three millimetres in its internal diameter, and a dilated portion sixteen centimetres long and twelve millimetres in its internal diameter. This tube contains the granular pumice-stone which serves as the absorbent material in this method ; *b*—is the gas-meter ; and *c*—a Chapman water pump.

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